Investigational Study on Strength Of Fiber Concrete Using Bamboo

BHADRIRAMAN K S
Research Scholar, Department of Civil Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu, India, bhadriraman@gmail.com

Dr PRIYA RACHEL*
Project Guide, Department of Civil Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu, India, priyarachel.sse@saveetha.com

Abstract

Aim: The present study investigated the compressive strength of Bamboo Fiber Reinforced Concrete (BFRC) compared with conventional concrete. Materials and Methods: The methods utilized in this article include the preparation of concrete mixtures with 0.5 percentage of bamboo Fiber content, casting and curing of the specimens, and testing for compressive strength using a compression testing machine. This study utilized bamboo Fibers, mortar, fine and coarse aggregates, and water as its ingredients. Before evaluation for compressive strength with a universal testing equipment, specimens were cast and cured for 28 days. Bamboo Fiber Reinforced Concrete (BFRC) specimens (n=10) were then compared to conventional concrete specimens (n=10) through statistical analysis using G-power software with a power of 0.8 and a 95% confidence interval. Results: The inclusion of 0.5% bamboo fiber in standard concrete was found to increase its compressive strength, with the compressive strength of ordinary concrete being 27 MPa and that of bamboo-reinforced concrete being 30 MPa. This indicates a 5.6% improvement in compressive strength. Conclusion: The outcomes of this research will present vital data regarding the sustainability of bamboo Fibers as a reinforcing concrete material and their effect on the resulting material's compressive strength.

Keywords: *Compressive strength, Concrete, Novel Bamboo Fiber, Casting, Curing, Conventional concrete, Fine aggregate, Reinforced concrete.*

Introduction

Bamboo is a natural resource that is abundant, fast-growing, and sustainable (Goh, Yap, and Tong 2019). The high strength-to-weight ratio of bamboo makes it a desirable construction material, and its potential as a concrete reinforcement has been investigated in recent years (Su et al. 2021). Bamboo Fiber reinforced concrete (BFRC) is a composite material that blends the attributes of bamboo fibres with concrete to produce a material with high tensile strength and flexibility from the bamboo fibres, as well as high compressive strength and durability from the concrete. The inclusion of bamboo fibres into concrete has the ability to boost the material's strength and tensile strength, making it more difficult to breaking and failure (Li et al. 2020). In this study, BFRC specimens were prepared with 0.5 percentage of bamboo Fiber content, and the compressive strength was tested and compared to that of conventional concrete specimens. This research involves the production of concrete

mixtures including varying proportions of bamboo Fiber, the casting and curing of specimens, and testing for compressive strength with a compression testing machine (Sellami et al. 2022). The findings of this study will shed light on the viability of bamboo Fibers as a reinforcing element in concrete and their impact on the resulting material's compressive strength. Bamboo fibres have a broad variety of applications, such as Reinforcement in building material, Textile production, Biomaterials, Paper manufacture, Filtration, and Automotive sector.

Recent study indicates that the addition of fibres to concrete can greatly enhance its mechanical qualities, as proven by the huge number of publications published on the subject (Noori et al. 2021; Bittner and Oettel 2022; Garrouri et al. 2022; Asare 2019). A search on IEEE Explore and Google Scholar revealed a substantial number of articles available on the topic, including 45 papers on IEEE Explore and 215 articles on Google Scholar. Norliana and Siew Choo (Norliana and Siew Choo 2021) found that incorporating bamboo fibres into concrete improves its compressive strength, flexural strength, and elastic modulus in their uniaxial compression tests. Gao et al. (Gao et al. 2022) compared the properties and performance of BFRC to conventional concrete, finding that BFRC had greater compressive strength, toughness and ductility. Javadian et al. (Javadian et al. 2019) explored the use of bamboo fibres as a reinforcing material for concrete and found that it strengthens the compressive strength as well as the durability and sustainability of concrete. More and Subramanian (More and Subramanian 2022) found that adding natural fibres to concrete increases its mechanical qualities, including compressive strength, flexural strength, and impact resistance. Thanushan et al. (Thanushan et al. 2021) found that using coconut fibres in concrete can increase its strength and longevity while reducing the amount of cement required. Ahamed (Shadheer Ahamed, Ravichandran, and Krishnaraja 2021) observed that the incorporation of natural fibres like as jute, coir, and sisal strengthens the mechanical characteristics of concrete, specifically its compressive strength and flexural strength. Rauf et al. (Rauf et al. 2020) noticed that the curing circumstances had a substantial effect on the mechanical attributes of natural fibre reinforced concrete, with the optimum results produced under moist curing conditions. Kouta, Saliba, and Saiyouri (Kouta, Saliba, and Saiyouri 2020) found that adding natural fibres to concrete reduces its shrinkage and that different types of fibres have varying effects on concrete's shrinkage.

The main disadvantage of standard concrete is its relatively low compressive strength compared to other building materials. This can limit its use in certain applications and require the use of additional reinforcement materials. To overcome these restrictions, a novel form of Bamboo fiber-reinforced concrete (BFRC) can be utilized. The purpose of this study is to compare the compressive strength of BFRC to that of standard concrete and to evaluate the efficiency of bamboo fibres as a reinforcement material used in concrete. The compressive strength of the finished product can be greatly enhanced by introducing bamboo fibres into the concrete mixture. The research will provide valuable insights into the potential of bamboo fibers as a sustainable and eco-friendly alternative to traditional reinforcement materials in the construction industry.

MATERIALS AND METHODS

The experiment was carried out in the Mechanics Laboratory of the Civil Engineering Department at Saveetha School of Engineering. In this study, BFRC specimens were prepared with 0.5 percent of bamboo Fiber content by weight of cement. The bamboo Fibers were obtained from a Js Readymix Concrete and were of a length of 12 mm. Conventional concrete specimens were also prepared as a

reference. The concrete mixtures were made according to a standard mix proportion with a water-cement ratio of 0.50. The bamboo Fibers were included into the concrete mixture during the mixing process. The specimens were cast and cured in a controlled environment for 28 days. After the curing period, the compressive strength of the BFRC and conventional concrete specimens was tested using a compression testing machine. The tests were performed in accordance with ASTM standards. The research study had a sample size of 20, which was divided into two groups of 10 each. The first group consisted of conventional concrete, while the second group used a novel type of Bamboo Fiber reinforced concrete. The sample size for the study was determined on the previous research, as noted by Zhang et al. (Zhang et al. 2020). The data analysis was conducted using G-power software with a significance level of 0.05 and a power of 0.20. The results are reported with a 95% confidence interval.

Conventional concrete

Conventional concrete is a type of construction material that is made by mixing cement, water, fine aggregate (such as sand), and coarse aggregate (such as gravel or crushed stone) together. When mixed and placed in the desired location, the concrete will harden and set into a solid form. Conventional concrete is a versatile and widely used material in the construction industry, with applications ranging from building foundations and roads to bridges and skyscrapers. The strength of the concrete is determined by the mix proportion and curing time. Conventional concrete can also be classified based on its compressive strength, for example M20, M25, M30, etc. where M stands for Mix and the number 20, 25, 30 etc. represents the compressive strength of the concrete in MPa. The main reason for poor compressive strength is improper mix proportion. If the mix proportion of the concrete is not correct, it may not have the desired strength. For example, if the water-cement ratio is too high, the concrete will have a lower compressive strength due to the excess water which hinders the hydration process of cement. Poor compressive strength can make concrete more vulnerable to cracking and failure under load, especially in structures that are subjected to heavy loads or dynamic forces. This can compromise the structural integrity of the building, making it less safe and durable.

Bamboo Fiber reinforced concrete

Fiber reinforced concrete (FRC) is a type of concrete that improves its qualities by incorporating fibres into the concrete mixture. BFRC is a form of FRC in which bamboo fibres are used as reinforcement. The compressive strength test is a typical method for determining the strength qualities of BFRC. A cylindrical or cubic specimen of BFRC is subjected to a compressive load till failure, with measurements of 150mm x 150mm x 150mm (or 100mm x 100mm x 100mm). To compute the compressive strength of the BFRC, the highest load at failure is then calculated by the specimen's cross-sectional area. When bamboo fibres are added to the concrete mixture in small amounts, such as 0.5% by volume, the compressive strength of the concrete can be greatly increased. The inclusion of bamboo fibres to concrete improves its microstructure by strengthening the link between the binder and aggregate, resulting in a better compressive strength. The high strength-to-weight ratio of bamboo fibres enables the addition of more fibres without increasing the concrete's weight, hence enhancing its compressive strength. BFRC with 0.5% bamboo fibers also shows improved toughness and ductility, which allows the concrete to withstand deformation before failure. This makes BFRC with 0.5% bamboo fibers more suitable for structures that will be subjected to dynamic forces or heavy loads. In addition to the improved compressive strength, the use of bamboo fibers in BFRC also makes it a more sustainable and eco-friendly

option for construction projects. Bamboo is a renewable material, and its use in building can assist the construction industry minimise its carbon footprint. The compressive strength test is a basic method used to measure the performance of bamboo fiber-reinforced concrete (BFRC), and is vital for determining the usefulness of bamboo fibres as a concrete reinforcement material. The test findings can be used to evaluate the compressive strength of BFRC to that of ordinary concrete and to identify the optimal proportion of bamboo fibres to be added to the BFRC mixture.

Statistical Analysis

The independent samples t-test was conducted using IBM SPSS (Yockey 2017) software. The statistical analysis was conducted on the test results to determine the significance of the differences in compressive strength between the BFRC and conventional concrete specimens. The p-value from the t-test can be used to analyze the significance of the differences in compressive strength between the BFRC and conventional concrete specimens. The statistical analysis included calculating the mean, standard deviation, and coefficient of variation for each group of test results, as well as performing a t-test to measure the means of the two groups. The data was also plotted in a graph for visual representation of the results. In this case, the independent variable is the type of concrete (BFRC or conventional concrete), and the dependent variable is the compressive strength.

RESULTS

Figure 1 depicts a bar graph comparing the compressive strength of normal concrete and BFRC. The X-axis of the graph is labeled as "Types of Concrete" and it shows two bars, one for conventional concrete and one for BFRC. The Y-axis of the graph is labeled as "Mean Compressive Strength (MPa)" and it shows the scale of compressive strength. The normal concrete has a compressive strength of 27 MPa, whereas the novel BFRC has a compressive strength of 30 MPa.

Figure. 1. The bar graph compares the compressive strength of conventional concrete and Bamboo Fiber Reinforced Concrete (BFRC). The X-axis of the graph is labeled as "Types of Concrete" and it shows two bars, one for conventional concrete and one for BFRC. The Y-axis of the graph is labeled as "Mean Compressive Strength (MPa)" and it shows the scale of compressive strength. The conventional concrete bar is shown with a mean compressive strength of 27 MPa and BFRC bar is shown with a mean compressive strength of 30 MPa. The error bars in the graph represent ±1 standard deviation, which is a measure of the spread of the data. The error bars are used to indicate the 95% confidence interval of the mean compressive strength, providing an estimate of the uncertainty around the mean.

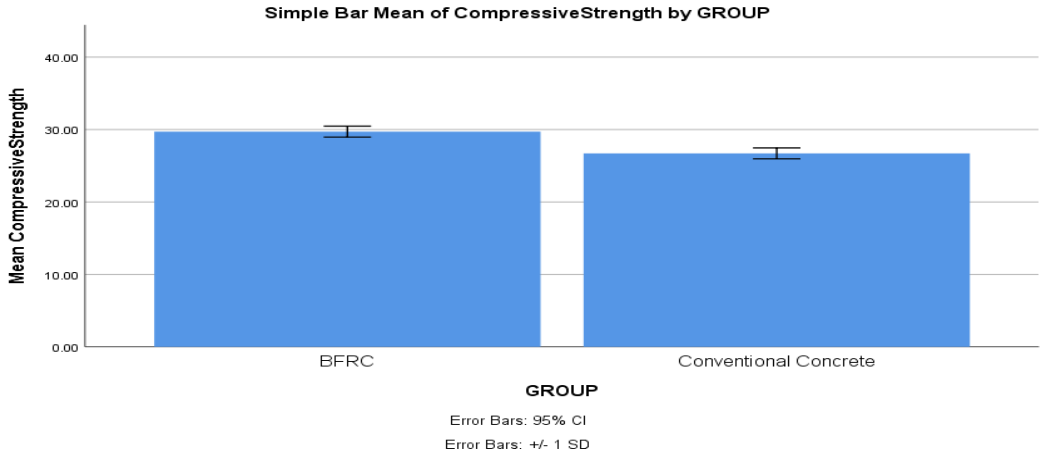

Table 1. This table shows the results of a compressive strength test on conventional concrete and bamboo fiber reinforced concrete (BFRC). The table includes ten test results, each with a different test size. The average compressive strength of conventional concrete is 27MPa and that of BFRC is 30MPa. Based on the results, it can be seen that the compressive strength of BFRC is generally higher than that of conventional concrete.

SI.No.	Test Size	Compressive Strength	
		Conventional concrete	BFRC
1	Test1	23.5	29.5
2	Test2	25.2	31.2
3	Test3	26.1	27.4
4	Test4	25.8	31.7
5	Test5	27.9	30
6	Test6	31.5	28.5
7	Test7	26.3	29.3
8	Test8	25.1	31.1
9	Test9	27.4	30.4
10	Test10	31.2	30.9

The findings of a compressive strength test on normal concrete and bamboo fibre reinforced concrete are presented in Table 1. The table contains ten test results with varying test sizes. The median compressive strength of normal concrete is 27MPa, whereas the median compressive strength of BFRC is 30MPa.

Table. 2. The table compares the compressive strength of Bamboo Fiber Reinforced Concrete (BFRC) and conventional concrete. The results are presented as the mean, standard deviation, and standard error mean for each group. The mean compressive strength for BFRC is 30 MPa, which is higher than the mean compressive strength for conventional concrete at 27 MPa. The standard deviation for BFRC is 0.220 MPa, indicating that the data is closely grouped around the mean. On the other hand, the standard deviation for conventional concrete is 0.545 MPa, indicating that the data is more spread out. The standard error mean for BFRC is 0.080 MPa, indicating a high level of precision in the mean measurements. In contrast, the standard error mean for conventional concrete is 0.467 MPa, indicating a lower level of precision in the mean measurements.

Group		N	Mean	Standard Deviation	Standard Error Mean
Compressive Strength	BFRC	10	30	0.220	0.080
	Conventional Concrete	10	27	0.545	0.467

The table 2 compares compressive strength of BFRC and conventional concrete, showing the mean, standard deviation and standard error mean for each group. BFRC has a mean compressive strength of 30 MPa which is higher than conventional concrete's mean of 27 MPa. BFRC has a smaller standard deviation and standard error mean indicating a higher level of precision and consistency in measurements.

Table 3: The table presents the results of a T-test that compares the compressive strength of Bamboo Fiber Reinforced Concrete (BFRC) and conventional concrete. The test has been performed with a significance level of 0.001 and a confidence interval of 95%. The results are presented in terms of the significance (2-tailed), mean difference, standard error difference, and lower and upper interval difference. The test indicates that there is a statistically significant difference between the compressive strength of BFRC and conventional concrete, with a level of Std. Error Difference of 0.223.

Group		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval (Lower)	95% Confidence Interval (Upper)
Compressive strength	Equal variances assumed	2.521	0.185	1.709	15	0.001	0.334	0.223	-0.190	0.775
	Equal variances not assumed			1.709	5.903	0.001	0.334	0.223	-0.189	0.767

Table 3 analyzes the compressive strength of BFRC and standard concrete using a T-test. The T-test was conducted with a significance threshold of 0.001 and a 95% confidence interval,. The results are provided in terms of the significance (2-tailed), the mean difference, the standard error difference, and the difference between the lower and higher intervals.

DISCUSSION

This study demonstrates that the use of bamboo fibres as reinforcement in concrete can increase its compressive strength and is a feasible alternative to standard reinforcement techniques. Based on the results of the study, the inclusion of 0.5% bamboo fibres to the concrete mixture greatly improves the BFRC's compressive strength. The average compressive strength of BFRC specimens containing 0.5% bamboo fibre was 3MPa more than that of standard concrete specimens. This improvement in compressive strength can be ascribed to bamboo Fibers' high strength-to-weight ratio, which can also improve the concrete's toughness and ductility. The findings of the compressive strength test on 0.5% BFRC and normal concrete indicate that BFRC has a greater mean compressive strength of 30 MPa compared to 27 MPa for conventional concrete. The standard deviation of BFRC is also smaller, indicating that the data is closely grouped around the mean, and the standard error mean is also smaller, indicating a high level of precision in the mean measurements. These results suggest that BFRC has a higher compressive strength than conventional concrete.

Some similar studies are Giridharan (Giridharan, V., and M. 2019) examined the effect of different percentages of bamboo fiber content on the characteristics of BFRC. They discovered that increasing the bamboo fibre

content from 0% to 2% enhanced the BFRC's compressive strength, modulus of elasticity, and impact strength considerably. Alyousef (Alyousef et al. 2022) discovered that adding natural fibres to concrete increased its compressive strength by an average of 20% compared to the standard concrete. The average compressive strength of natural fibre reinforced concrete was determined to be 65 MPa. The use of ash from palm oil to natural fibre reinforced concrete increased its compressive strength by an average of 35 MPa, according to Alaskar (Alaskar et al. 2021). In addition, the inclusion of palm oil fuel ash enhanced the durability of the concrete, according to the study. Saadun (Saadun et al. 2022) discovered that adding bamboo fibres to concrete increased its compressive strength by an average of 25% compared to the standard concrete. The compressive strength of bamboo fibre reinforced concrete was determined to be 55 MPa.

The limitations of this study include the small sample size of 20, which may not be representative of the entire population. Additionally, only 0.5% bamboo fibers were used in the BFRC mixture, and it would be beneficial to explore the optimal percentage of bamboo fibers that can be added to concrete for maximum compressive strength. Future work could include repeating the study with a larger sample size and testing a range of percentages of bamboo fibers to determine the optimal amount for maximum compressive strength. It could also be beneficial to explore the use of other types of fibers, such as synthetic fibers, in conjunction with bamboo fibers to study their combined effect on compressive strength.

CONCLUSION

In conclusion, the study aimed to investigate the compressive strength of 0.5% Bamboo Fibre Reinforced Concrete (BFRC) compared to conventional concrete. The results showed that BFRC had a higher mean compressive strength of 30 MPa compared to conventional concrete's mean of 27 MPa. The proposed BFRC had a higher average compressive strength of 3 MPa compared to that of standard concrete. This study provides evidence that the use of bamboo fibers as reinforcement in concrete can improve its compressive strength and can be a viable alternative to conventional reinforcement methods.

DECLARATION

Conflicts of Interest

No conflict of interest in this manuscript

Authors Contributions

Bhadriraman was involved in data collection, data analysis and manuscript writing. priyarachel was involved in conceptualization, data validation, and critical review of manuscripts.

Acknowledgment

The authors would like to express their gratitude towards Saveetha School of Engineering, Saveetha Institute of Medical And Technical Sciences (Formerly known as Saveetha University) for successfully carrying out this work.

Funding: We thank the following organizations for providing financial support that enabled us to complete the study.

1. GPR BUILDERS.
2. Saveetha University
3. Saveetha Institute of Medical And Technical Sciences
4. Saveetha School of Engineering

References

Alaskar, Abdulaziz, Hisham Alabduljabbar, Abdeliazim Mustafa Mohamed, Fahed Alrshoudi, and Rayed Alyousef. 2021. “Abrasion and Skid Resistance of Concrete Containing Waste Polypropylene

Fibers and Palm Oil Fuel Ash as Pavement Material." Construction and Building Materials 282 (May): 122681.

Alyousef, Rayed, Hossein Mohammadhosseini, Ahmed Farouk Deifalla, Shek Poi Ngian, Hisham Alabduljabbar, and Abdeliazim Mustafa Mohamed. 2022. "Synergistic Effects of Modified Sheep Wool Fibers on Impact Resistance and Strength Properties of Concrete Composites." Construction and Building Materials 336 (June): 127550.

Asare, B. J. 2019. "Mechanical Optimisation of Earth-Based Composites Materials Reinforced with Treated Bamboo Fibers for Affordable Housing." https://air.ashesi.edu.gh/handle/20.500.11988/568.

Bittner, Can Mark, and Vincent Oettel. 2022. "Fiber Reinforced Concrete with Natural Plant Fibers—Investigations on the Application of Bamboo Fibers in Ultra-High Performance Concrete." Sustainability: Science Practice and Policy 14 (19): 12011.

Gao, Xun, Deju Zhu, Shutong Fan, Md Zillur Rahman, Shuaicheng Guo, and Feng Chen. 2022. "Structural and Mechanical Properties of Bamboo Fiber Bundle and Fiber/bundle Reinforced Composites: A Review." Journal of Materials Research and Technology 19 (July): 1162–90.

Garrouri, Sabrine, Wissem Lakhal, Amar Benazzouk, and Ezeddine Sediki. 2022. "Potential Use of Alfa Fibers in Construction Material: Physico-Mechanical and Thermal Characterisation of Reinforced Specimen." Construction and Building Materials 342 (August): 127787.

Giridharan, R., S. Raatan V., and P. Jenarthanan M. 2019. "Experimental Study on Effect of Fiber Length and Fiber Content on Tensile and Flexural Properties of Bamboo Fiber/epoxy Composite." Multidiscipline Modeling in Materials and Structures 15 (5): 947–57.

Goh, Yingxin, Soon P. Yap, and Teong Y. Tong. 2019. "Bamboo: The Emerging Renewable Material for Sustainable Construction." Reference Module in Materials Science and Materials Engineering. Elsevier, 1–14.

Javadian, Alireza, Ian F. C. Smith, Nazanin Saeidi, and Dirk E. Hebel. 2019. "Mechanical Properties of Bamboo Through Measurement of Culm Physical Properties for Composite Fabrication of Structural Concrete Reinforcement." Frontiers in Materials 6. https://doi.org/10.3389/fmats.2019.00015.

Kouta, Nathalie, Jacqueline Saliba, and Nadia Saiyouri. 2020. "Effect of Flax Fibers on Early Age Shrinkage and Cracking of Earth Concrete." Construction and Building Materials 254 (September): 119315.

Li, Zhihan, Chaoji Chen, Ruiyu Mi, Wentao Gan, Jiaqi Dai, Miaolun Jiao, Hua Xie, Yonggang Yao, Shaoliang Xiao, and Liangbing Hu. 2020. "A Strong, Tough, and Scalable Structural Material from Fast-Growing Bamboo." Advanced Materials 32 (10): e1906308.

More, Florence More Dattu Shanker, and Senthil Selvan Subramanian. 2022. "Impact of Fibers on the Mechanical and Durable Behaviour of Fiber-Reinforced Concrete." Buildings 12 (9): 1436.

Noori, Adel, Yubin Lu, Pooya Saffari, Jinguan Liu, and Jinfu Ke. 2021. "The Effect of Mercerization on Thermal and Mechanical

Properties of Bamboo Fibers as a Biocomposite Material: A Review." Construction and Building Materials 279 (April): 122519.

Norliana, Bakar, and Chin Siew Choo. 2021. "Performance of Bamboo Fiber Reinforced Composites: Mechanical Properties." Key Engineering Materials 879 (March): 284–93.

Rauf, Momina, Wasim Khaliq, Rao Arsalan Khushnood, and Iftikhar Ahmed. 2020. "Comparative Performance of Different Bacteria Immobilized in Natural Fibers for Self-Healing in Concrete." Construction and Building Materials 258 (October): 119578.

Saadun, Nor Syazwani, Masni A. Majid, Mohd Hanif Ismail, and Suraya Hani Adnan. 2022. "An Overview on Physical and Mechanical Properties of Bamboo as a Natural Reinforcement in Concrete." IOP Conference Series: Earth and Environmental Science 1022 (1): 012049.

Sellami, Asma, Djamila Bouayad, Amar Benazzouk, Sofiane Amziane, and Mouloud Merzoud. 2022. "Study of Toughness and Thermal Properties of Bio-Composite Reinforced with Diss Fibers for Use as an Insulating Material." Energy and Buildings 276 (December): 112527.

Shadheer Ahamed, M., P. Ravichandran, and A. R. Krishnaraja. 2021. "Natural Fibers in Concrete – A Review." IOP Conference Series. Materials Science and Engineering 1055 (1): 012038.

Su, Jingwen, Nanjing Technical Vocational College, Haitao Li, Zhenhua Xiong, Rodolfo Lorenzo, Joint International Research Laboratory of Bio-composite Building Materials and Structures, Nanjing Forestry University, College of Civil Engineering, Nanjing Forestry University, Ganzhou Sentai bamboo company LTD, Joint International Research Laboratory of Bio-composite Building Materials and Structures, Nanjing Forestry University, and University College London. 2021. "Structural Design and Construction of an Office Building with Laminated Bamboo Lumber." Sustainable Structures 1 (2). https://doi.org/10.54113/j.sust.2021.000010.

Thanushan, Kirupairaja, Youganathan Yogananth, Pooraneswaran Sangeeth, Juthathatheu Gracian Coonghe, and Navaratnarajah Sathiparan. 2021. "Strength and Durability Characteristics of Coconut Fiber Reinforced Earth Cement Blocks." Journal of Natural Fibers 18 (6): 773–88.

Yockey, Ronald D. 2017. SPSS® Demystified: A Simple Guide and Reference. Routledge.

Zhang, Dong, Kang Hai Tan, Aravind Dasari, and Yiwei Weng. 2020. "Effect of Natural Fibers on Thermal Spalling Resistance of Ultra-High Performance Concrete." Cement and Concrete Composites 109 (May): 103512.